A8912-3
10/20/88

SEG

Special Report

Geophysical Activity in 1987

Compiled by the

Geophysical Activity Committee

Reprinted from GEOPHYSICS: THE LEADING EDGE OF EXPLORATION, Vol. 7, No. 8, August 1988

Special Report
Geophysical Activity in 1987

Russell J. Senti*

Report of the SEG Geophysical Activity Committee. Members of the Committee are Russell J. Senti, Chairman; Karen Goodfellow, Assistant Chairman; and Jesus A. Bilboa, Lionel Cane, Charles E. Curtis, John Doherty, Harry Espey, Lin Evans, Ronald Hartman, Dan D. Hollis, Richard Hopkins, Fritz P. Kronberger, Robert C. Lucas, Wes Meyers, Gerald Montgomery, James Sides, Mike Spradley, Frank Stirling, Paul Stoffa, Tommy Tillery, and Don Watts.

Introduction

Statistical data on worldwide geophysical activity in 1987 are presented in this report. Data were gathered from survey questionnaires that were mailed to over 475 oil companies, contractors, government agencies, and institutions throughout the free world. Information has been collected from all users of geophysical techniques in the areas of petroleum, mining, groundwater, and geothermal exploration, and from those who employ geophysical methods in engineering, environmental, oceanography, and research. Two hundred fifteen questionnaires were returned with data for this report. This compares to 251 questionnaires returned with data for the 1986 report and 214 returns for the 1985 report.

Detailed data were gathered on airborne, drill-hole, land, marine, and transition zone geophysical surveys. Statistics were compiled on miles of coverage, number of stations, drill-hole footage, time spent in crew-months or man-months, and acquisition costs. Data not supplied on the questionnaires by the respondents were estimated on the basis of statistical averaging for the area and techniques reported. This process is necessary to avoid distortion of individual statistical items.

This report, when compared to past annual reports, provides a basis for detecting and analyzing trends in technological developments and exploratory trends in geographical areas. Changes in these trends reflect the influence of factors such as oversupply of a particular natural resource, technological advances, and changes in economic conditions, governmental regulations, production controls by a country or countries, and exploration philosophy. Cost figures are also sensitive to many factors such as operational environment, length and nature of the survey, type of instrumentation, etc. Unit costs reported by universities are substantially lower than those reported by industry due to the use of student labor and donated equipment. These costs, however, must be averaged with industry costs to accommodate the format of the report. Therefore, when examining unit cost figures, one must be aware of the broad spectrum of activity embraced by individual categories.

1987 highlights

Worldwide expenditures on geophysical exploration in 1987 were down 23.3 percent from 1986 (see Table 1). This reduction reflects the decrease in total petroleum expenditures of 23.6 percent. Petroleum exploration expenditues declined 24.7 percent while expenditures for petroleum development increased 125.8 percent over 1986 levels. Use of geophysics for petroleum development in 1987 showed the largest increase for land activity, up nearly 500 percent. Petroleum development land activity captured 2.4 percent of the total petroleum expenditures for land activity in 1987. Airborne and transition zone petroleum development expenditures are reported for the first time in this report.

Table 1. Total worldwide expenditures in US$ (thousands) by survey type and objective.

Type	Petroleum[1]		Minerals	Environmental	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
	Exploration	Development								
Land	809,394	20,161	13,076	443	2,100	1,095	1,505		3,217	850,990
Transition zone	10,091	25								10,116
Marine	541,053	9,657	62		8,580			1,458	6,190	566,999
Airborne	13,405	32	13,705	92				300	802	28,336
Drill hole	1,504	294	58	91	235	30	283		184	2,679
Total	1,375,447	30,169	26,901	626	10,914	1,125	1,788	1,758	10,393	1,459,120

[1]Includes processing and interpretation costs for land and marine. See text for details.

Note: All tables in this report where figures are expressed in thousands of dollars have been rounded off as individual items; but the computer keeps track of all the truncated numbers and then the sums of the individual items are rounded off. As a result of this procedure, the rounded individual items may not add up precisely to the rounded sums.

*Texaco Inc., 4601 DTC Blvd., Denver, CO 80237.

Printed in the U.S.A.

Overall, total petroleum expenditures, which accounted for 96.3 percent of the total expenditures in 1987, declined in all areas except airborne and drilled hole: land (−24.2%), marine (−23.2%), and transition zone (−49.9%).

Expenditures for engineering (+1.8%) and mining (+.1%) increased slightly from 1986. All other survey objectives showed decreases: environmental (−77.3%), oceanography (−50.8%), research (−25%), groundwater (−20.7%), and geothermal (−2.1%). The continued decline in expenditures for the use of geophysics in these areas affected the United States, Australia/New Zealand, Mexico, Europe, and Africa the most.

Distribution of expenditures by geographic area and survey objective is shown in Table 2. Only 31.8 percent of all expenditures for geophysical work was spent in the United States, compared to 32 percent in 1986, 44 percent in 1985, and over 50 percent in 1984. There was $1.4 billion less spent on geophysical exploration in the U.S. in 1987 than in 1984. The following areas showed a decrease in total geophysical expenditures compared to 1986: U.S. (−23.8%), Canada (−3.8%), Mexico (−35.8%), Europe (−37.9%), Africa (−53.9%), Middle East (−.3%), Far East (−3.3%), and Australia/New Zealand (−30.8%). Only one area showed an increase in 1987 over 1986. South America had an 18.5% increase in expenditures for geophysical work with all of this increase in the petroleum exploration objective.

The costs of processing and interpretation are included in Figures 1 and 2 and the petroleum columns of Tables 1 and 2. The remaining columns in Tables 1 and 2 and all of Tables 3-17 show acquisition costs only. Average costs of processing and interpretation were obtained from various processing contractors and oil companies to arrive at a figure of U.S. $450 per line-mile. This figure is down 20 percent from the one used for the 1985 report.

Petroleum exploration/development

Over 96 percent of all geophysical dollars were spent on petroleum exploration and development (US $1.405 billion) in 1987. Expenditures for petroleum exploration and development declined in the following areas: United States (−23.2%), Canada (−3.5%), Mexico (−35.4%), Europe (−39.6%), Africa (−56%), Far East (−2.7%), and Australia/New Zealand (−30.9%). The Middle East showed a small increase (+.8%) over 1986 and South America had the largest increase (+17.7%) in 1987. However, due to the large declines in U.S. and Mexico activity, petroleum exploration and development expenditures declined 14.5 percent in the Western Hemisphere. Eastern Hemisphere activity declined 33 percent over 1986. A 10-year history of

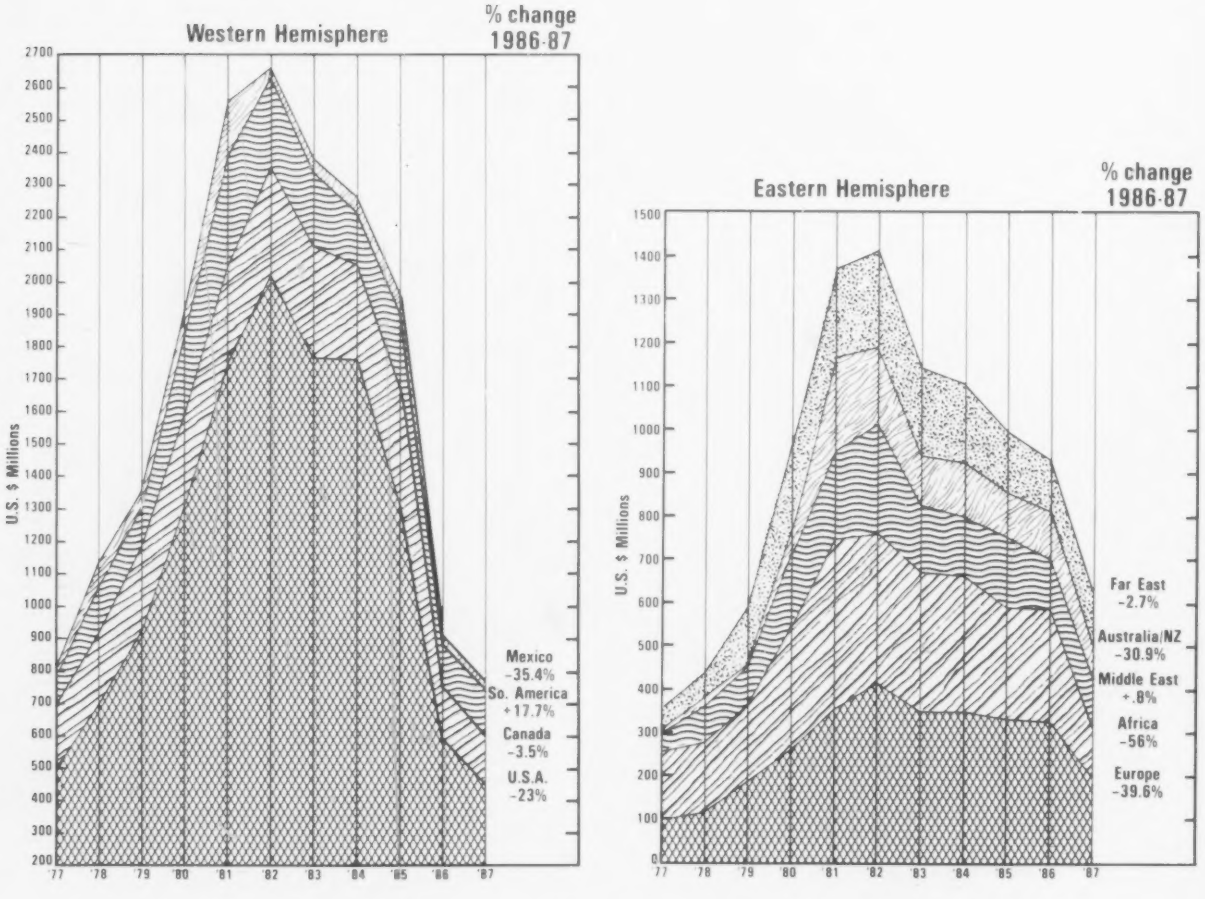

FIG. 1. Total expenditures on petroleum exploration and development, 1977-87.

Table 2. Total worldwide expenditures in US$ (thousands) by area and survey objective.

Area	Petroleum[1]		Minerals	Environmental	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
	Exploration	Development								
International	17,010							708	1,929	19,647
U.S.A.	426,824	26,786	2,658	578	3,339	175	464	1,050	2,560	464,434
Canada	145,800		9,717	22	53				1,033	156,626
Mexico	18,138		5							18,143
South America	148,718		107		6	67			1,046	149,943
Europe	198,032	701	6,314		5,393		307		738	211,486
Africa	110,550	904	4,367		1,086		742		186	117,834
Middle East	118,778				100		76			118,954
Far East	120,769		1,388		932	833	49		1,041	125,013
Australia/ New Zealand	70,828	1,778	2,345	26	5	50	150		1,859	77,040
Total	1,375,447	30,169	26,901	626	10,914	1,125	1,788	1,758	10,393	1,459,120

[1]Includes processing and interpretation costs. See text for details.

petroleum exploration and development activity in both hemispheres is shown in Figure 1.

Petroleum seismic surveys

The seismic method accounted for 98 percent of all expenditures in petroleum geophysical activity. This statistic plus the strong tendency for wildcatting to parallel seismic activity, has caused those interested in forecasts of petroleum exploration to regard seismic activity as a barometer for exploration. A 10-year history of the cost of petroleum seismic surveys in both the Eastern and Western Hemispheres is shown in Figure 2. In the Western Hemisphere, average acquisition costs per mile of land seismic surveys increased 13.6 percent, while marine costs decreased 10.3 percent. The increase in land seismic costs per mile could be attributed to an increase in "foothill shooting" in Canada and the U.S. These high cost, low production surveys

(Text continued on p. 42)

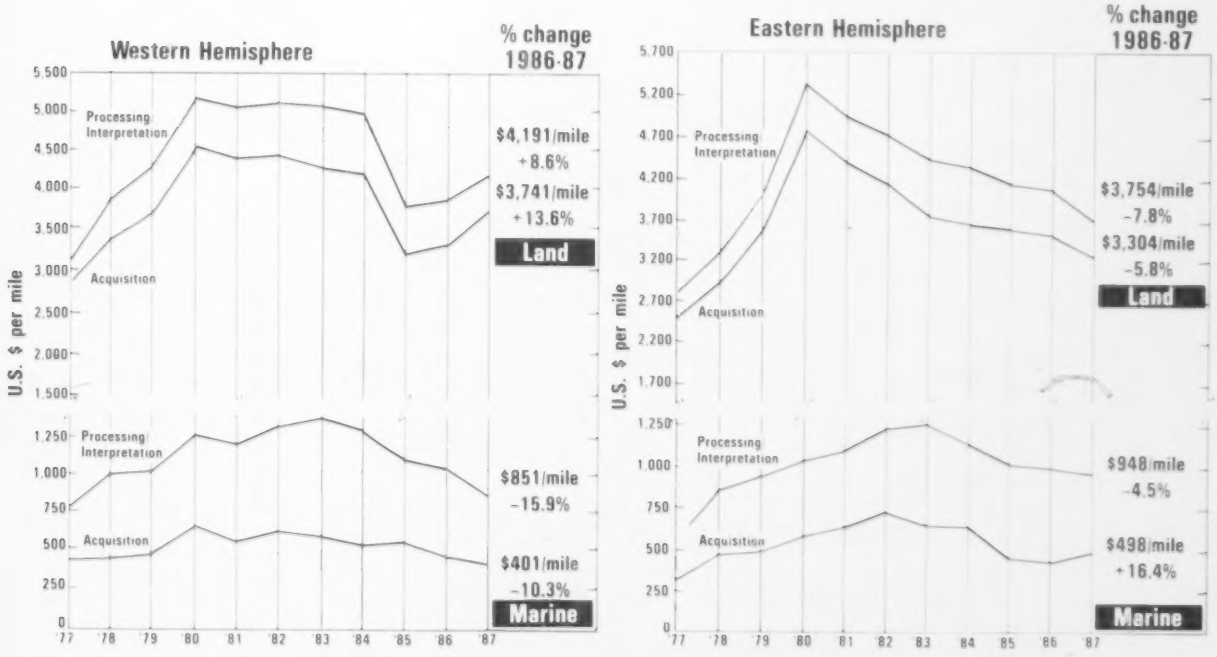

FIG. 2. Average cost per mile for petroleum seismic surveys, 1977-87.

Table 3. Worldwide petroleum land seismic activity.[1]

Area	Acquisition costs - US$	Line-miles	Crew-months		Crew-months total*	Average miles/month	Average cost/month	Average cost/mile
			Company*	Contract				
U.S.A.	228,052,738	52,450	229.0	1,108.5	1,337.5	39	170,507	4,348
	[1,904,000]	[85]	[4.0]	[1.7]	[5.7]	[15]	[334,035]	[22,400]
Canada	118,421,338	32,431	69.7	309.7	379.4	86	312,128	3,652
	[7,274,784]	[382]		[22.5]	[22.5]	[17]	[323,324]	[19,044]
Mexico	9,189,237	6,578		181.0	181.0	36	50,769	1,396
South America	76,247,705	24,008		328.7	328.7	73	231,967	3,176
Europe	54,509,138	14,223		266.8	266.8	53	204,307	3,832
Africa	83,452,711	22,698		330.6	330.6	69	252,428	3,677
Middle East	79,269,628	25,109		270.0	270.0	93	293,591	3,157
Far East	51,073,730	14,955		289.6	289.6	51	176,359	3,415
Australia/ New Zealand	26,942,823	12,378		127.7	127.7	96	210,985	2,176
Total	727,159,038	204,830	298.7	3,212.6	3,511.3	58	207,091	3,550
	[9,178,784]	[467]	[4.0]	[24.2]	[28.2]	[17]	[325,489]	[19,655]

Table 4. Worldwide petroleum land seismic line-miles by energy source and 3-D survey.[1]

Area	Dynamite	Compressed air	Implosive	Weight drop	Vibrator	3-D Surveys		Other	Total line-miles
						Line-miles	Square miles		
U.S.A.	19,357	1,227	38	1,018	27,105	3,360	[85]	345	52,450 [85]
Canada	19,242	1,675		883	10,521	110	[382]		32,431 [382]
Mexico	3,625				2,953				6,578
South America	12,757				10,336	915			24,008
Europe	4,255				9,968				14,223
Africa	9,155				11,868	1,675			22,698
Middle East	2,686			1,246	17,311	3,865			25,109
Far East	12,942				2,013				14,955
Australia/ New Zealand	1,279				11,099				12,378
Total	85,298	2,902	38	3,147	103,176	9,925	[467]	345	204,830 [467]

Table 5. Worldwide petroleum marine seismic activity.[1]

Area	Acquisition costs - US$	Line-miles	Crew-months		Crew-months total*	Average miles/month	Average cost/month	Average cost/mile
			Company*	Contract				
International	17,009,808	24,819		25.0	25.0	992	680,392	685
U.S.A.	99,653,975	263,727	54.2	159.5	213.7	1,234	466,327	378
	[4,140,000]	[11,600]		[16.0]	[16.0]	[725]	[258,750]	[357]
Canada	2,100,000	1,400		3.0	3.0	466	700,000	1,500
Mexico	1,900,000	7,100		4.0	4.0	1,775	475,000	267
South America	30,868,635	63,218	3.0	69.4	72.4	873	426,362	488
Europe	75,207,921	143,342		168.0	168.0	853	447,666	525
Africa	9,609,000	11,900		15.0	15.0	793	640,600	807
Middle East	14,069,880	35,000		25.0	25.0	1,400	562,795	401
Far East	29,824,900	72,169	7.0	62.6	69.6	1,037	428,519	413
Australia/ New Zealand	21,734,650	39,800	4.0	31.0	35.0	1,137	620,990	546
Total	301,978,769	662,475	68.2	562.5	630.7	1,050	478,799	456
	[4,140,000]	[11,600]		[16.0]	[16.0]	[725]	[258,750]	[357]

*Total includes government and university activity, if any.

[1]All data enclosed in [brackets] pertain to 3-D surveys reported in square miles.

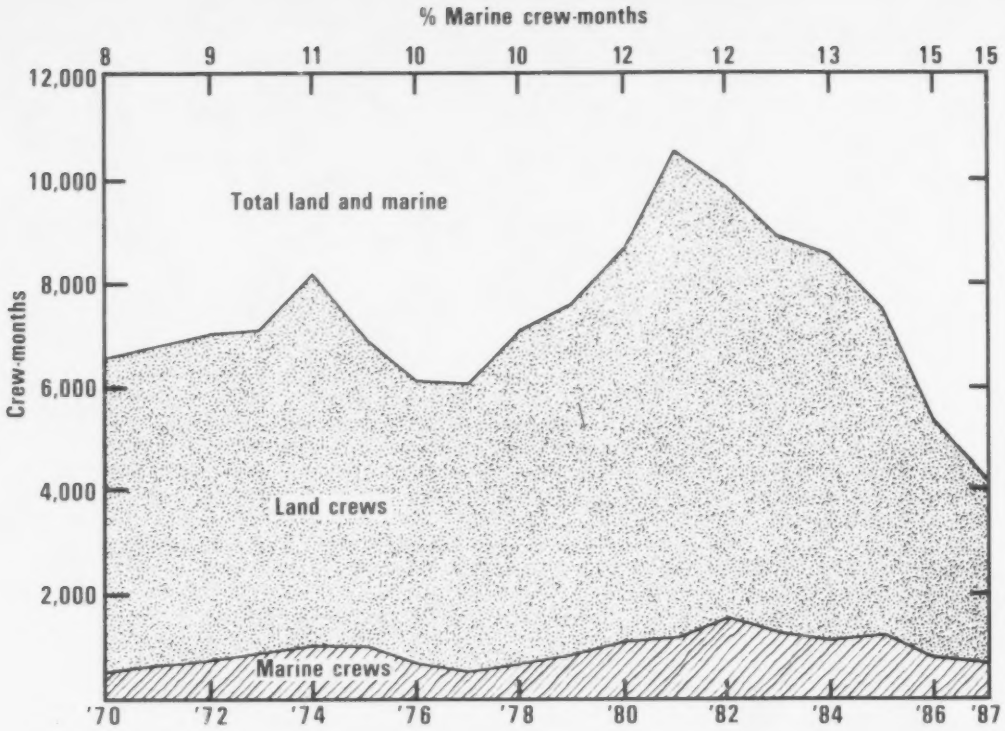

FIG. 3. Worldwide seismic activity in crew-months, 1970-87.

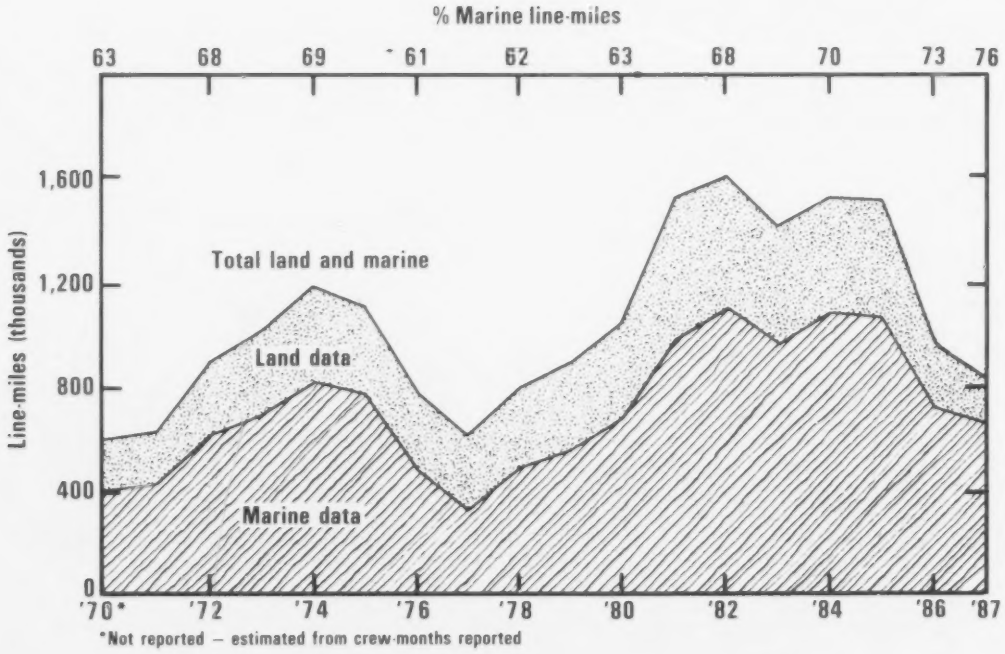

FIG. 4. Worldwide seismic activity in line-miles, 1970-87.

Table 6. Worldwide petroleum marine seismic line-miles by energy source and 3-D survey.[1]

Area	Compressed Air	Electrical	3-D Surveys		Total Line-miles
			Line-miles	Square miles	
International	24,819				24,819
U.S.A.	194,399		69,328	[11,600]	263,727 [11,600]
Canada	1,400				1,400
Mexico	7,100				7,100
South America	63,218				63,218
Europe	133,484	2	9,856		143,342
Africa	11,892	8			11,900
Middle East	35,000				35,000
Far East	64,400	401	7,368		72,169
Australia/ New Zealand	39,800				39,800
Total	575,512	411	86,552	[11,600]	662,475 [11,600]

[1]All data enclosed in [brackets] pertain to 3-D surveys reported in square miles.

Table 7. Worldwide average unit costs for petroleum surveys.

Area, survey type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew-month or man-month*	Average cost/ mile or (foot) or [station]
International						
Marine						
Seismic (*P*-wave)						
Compressed air	25.0	24,819	17,009,808	993	680,392	685
U.S.A.						
Land						
Seismic (*P*-wave)						
Dynamite	576.3	19,207	105,573,810	33	183,167	5,497
Compressed air	26.7	1,107	4,772,317	41	178,738	4,309
Implosive	1.0	38	774,000	38	774,000	20,368
Weight drop	26.4	1,018	2,678,272	38	101,181	2,631
Vibratory	613.4	26,802	99,627,739	44	162,406	3,717
Seismic (*S*-wave)						
Compressed air	10.0	120	1,260,000	12	126,000	10,500
Vibratory	4.3	48	563,600	11	131,070	11,742
Other	9.0	345	1,800,000	38	200,000	5,217
Seismic (refraction)						
Dynamite	5.0	150	475,000	30	95,000	3,167
Vibratory	2.5	255	200,000	102	80,000	784
Gravity	30.0	1,530	435,000	51	14,500	284
Gravity	9.0	[4,463]	159,400	[496]	17,711	[36]
Gravity	.2*	5	1,000	25*	5,000*	200
Magnetic	13.5	530	56,000	39	4,148	106
Magnetotelluric						
Natural field	2.0	[53]	195,000	[27]	97,500	[3,679]
Controlled source	1.0	[100]	33,000	[100]	33,000	[330]
VSPs	23.4	[76]	1,054,500	[3]	44,968	[13,875]
VSPs	1.0*	[3]	54,000	[3]*	54,000*	[18,000]
3-D seismic						
Line-miles	62.7	3,359	10,328,000	54	164,721	3,075
Square miles	5.7	85	1,904,000	15	334,035	22,400
Other	4.0	[12]	72,000	[3]	18,000	[6,000]
Transition zone						
Seismic (*P*-wave)						
Compressed air	10.0	300	1,000,000	30	100,000	3,333

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

Area, survey type, and method	Total crew months or man-months*	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
U.S.A., continued						
Marine						
Seismic (*P*-wave)						
Compressed air	177.3	194,399	81,732,449	1,096	460,984	420
Gravity	10.0	15,045	303,000	1,505	30,300	20
VSPs	3.4	[12]	288,800	[4]	84,941	[24,067]
3-D seismic						
Line-miles	36.4	69,328	17,921,525	1,905	492,350	259
Square miles	16.0	11,600	4,140,000	725	258,750	357
Airborne						
Gravity	1.0	1,050	105,000	1,050	105,000	100
Magnetic	138.2	551,200	6,231,510	3,988	45,084	11
Drill Hole						
Other	1.0	(3,300)	61,000	(3,300)	61,000	(18)
Other	24.0*	[15]	240,000	[1]*	10,000*	[16,000]
Canada						
Land						
Seismic (*P*-wave)						
Dynamite	192.1	18,180	62,694,412	95	326,228	3,448
Compressed air	17.5	1,675	6,418,000	96	366,743	3,832
Weight drop	6.0	850	1,200,000	142	200,000	1,412
Vibratory	143.1	10,460	39,736,744	73	277,685	3,799
Seismic (*S*-wave)						
Dynamite	1.0	50	500,000	50	500,000	10,000
Seismic (refraction)						
Dynamite	1.0	70	500,000	70	500,000	7,143
Dynamite	78.7*	942	6,600,000	12*	83,863*	7,006
Weight drop	1.3*	33	230,000	25*	176,923*	6,970
Vibratory	1.5*	61	240,000	41*	160,000*	3,934
Gravity	8.0*	235	47,000	29*	5,875*	200
Resistivity	1.0*	[4]	15,000	[4]*	15,000*	[3,750]
Magnotelluric						
Controlled source	.5	6	15,000	12	30,000	2,500
VSPs	.1	[3]	50,000	[30]	500,000	[16,667]
3-D seismic						
Line-miles	18.7	109	302,182	6	16,159	2,752
Square miles	22.5	381	7,274,784	17	322,607	19,079
Other	3.0	[100]	413,000	[33]	137,667	[4,130]
Other	1.2*	[35]	60,000	[28]*	48,000*	[1,714]
Transition zone						
Seismic (*P*-wave)						
Compressed air	1.5	95	1,300,000	63	866,667	13,684
Marine						
Seismic (*P*-wave)						
Compressed air	3.0	1,400	2,100,000	467	700,000	1,500
Airborne						
Magnetic	4.7	35,985	889,615	7,656	189,280	25
Drill hole						
Other	.2	(5,000)	40,000	(20,000)	160,000	(8)

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

Area, survey type, and method	Total crew months or man-months*	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations] / crew-month or man-month*	Average cost / crew month or man-month*	Average cost / mile or (foot) or [station]
Mexico						
Land						
Seismic (*P*-wave)						
Dynamite	115.0	3,625	5,200,823	32	45,225	1,435
Vibratory	66.0	2,953	3,988,414	45	60,431	1,351
Gravity	50.0	6,692	565,720	134	11,314	85
Magnetotelluric						
Natural field	12.0	[126]	111,287	[11]	9,274	[883]
VSPs	12.0	[34]	216,446	[3]	18,037	[6,366]
Marine						
Seismic (*P*-wave)						
Compressed air	4.0	7,100	1,900,000	1,775	475,000	268
South America						
Land						
Seismic (*P*-wave)						
Dynamite	157.2	12,757	41,905,000	81	266,571	3,285
Vibratory	158.5	10,336	32,055,250	65	202,241	3,101
Magnetotelluric						
Natural field	1.0	[24]	130,000	[24]	130,000	[5,417]
3-D seismic						
Line-miles	13.0	915	2,287,455	70	175,958	2,500
Transition zone						
Seismic (*P*-wave)						
Compressed air	9.0	700	1,600,000	78	177,778	2,286
Marine						
Seismic (*P*-wave)						
Compressed air	72.4	63,218	30,868,635	873	426,362	488
Gravity	2.0	9,921	52,000	4,961	26,000	5
Airborne						
Gravity	2.2	1,500	106,000	667	47,111	71
Magnetic	4.0	27,200	873,500	6,800	218,375	32
Europe						
Land						
Seismic (*P*-wave)						
Dynamite	107.4	4,255	24,374,800	40	226,953	5,729
Vibratory	159.4	9,968	30,134,338	63	189,049	3,023
Gravity	2.0	[768]	106,000	[384]	53,000	[138]
Resistivity	35.5	1,775	426,000	50	12,000	240
Electromagnetic						
Time domain	1.0	105	120,000	105	120,000	1,143
VSPs	33.6	[108]	813,750	[3]	24,219	[7,535]
Marine						
Seismic (*P*-wave)						
Compressed air	149.9	133,484	69,864,223	890	465,917	523
Electrical	21.0*	2	700,000	1*	33,333*	350,000
Gravity	6.2	15,376	80,000	2,460	12,800	5
3-D seismic						
Line-miles	18.0	9,856	4,643,698	546	257,126	471
Airborne						
Magnetic	10.0	30,000	946,000	3,000	94,600	32
Drill hole						
Other	.5	(26,000)	55,000	(52,000)	110,000	(2)

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

Area, survey type, and method	Total crew months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations] / crew-month or man-month*	Average cost / crew month or man-month*	Average cost / mile or (foot) or [station]
Africa						
Land						
Seismic (*P*-wave)						
Dynamite	149.5	9,155	31,390,841	61	209,972	3,429
Vibratory	157.1	11,868	47,872,870	76	304,729	4,034
Gravity	7.6	1,095	87,000	144	11,447	79
Gravity	24.5	[16,768]	1,066,616	[684]	43,535	[64]
Resistivity	1.5	75	18,000	50	12,000	240
VSPs	5.7	[19]	143,160	[3]	25,116	[7,535]
3-D seismic						
Line-miles	24.0	1,675	4,189,000	70	174,542	2,501
Marine						
Seismic (*P*-wave)						
Compressed air	15.0	11,892	8,709,000	793	580,600	732
Electrical	29.0*	8	900,000	1*	31,034*	112,500
Gravity	2.2	2,328	41,000	1,035	18,222	18
Airborne						
Magnetic	16.2	61,871	2,187,220	3,819	135,014	35
Drill hole						
Other	.5	(18,000)	33,000	(36,000)	66,000	(2)
Middle East						
Land						
Seismic (*P*-wave)						
Dynamite	40.3	2,686	10,678,580	67	264,977	3,975
Weight drop	12.5	1,246	4,078,510	100	326,281	3,272
Vibratory	190.2	17,311	54,766,538	91	287,942	3,164
VSPs	3.0	[10]	75,360	[3]	25,120	[7,536]
3-D seismic						
Line-miles	27.0	3,865	9,746,000	143	360,963	2,522
Marine						
Seismic (*P*-wave)						
Compressed air	25.0	35,000	14,069,880	1,400	562,795	402
Airborne						
Magnetic	.5	2,000	18,000	4,000	36,000	9
Drill hole						
Other	.2	(7,000)	35,000	(28,000)	140,000	(5)
Far East						
Land						
Seismic (*P*-wave)						
Dynamite	256.6	12,942	43,413,040	50	169,186	3,354
Vibratory	33.0	2,013	7,660,690	61	232,142	3,806
Gravity	1.0	[250]	15,000	[250]	15,000	[60]
Transition zone						
Seismic (*P*-wave)						
Dynamite	1.0	94	219,000	94	219,000	2,330
Compressed air	7.0	630	1,533,000	90	219,000	2,433
Marine						
Seismic (*P*-wave)						
Compressed air	57.0	64,400	25,340,900	1,130	444,577	393
Electrical	7.0	401	800,000	57	114,286	1,995
Gravity	6.2	18,157	71,000	2,905	11,360	4
Magnetic	2.0	7,177	179,000	3,589	89,500	25
3-D seismic						
Line-miles	5.5	7,367	3,684,000	1,320	660,215	500

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

Area, survey type, and method	Total crew months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Far East, continued						
Airborne						
Magnetic	5.5	34,916	1,363,000	6,348	247,818	39
Electromagnetic						
Frequency domain	2.5	13,916	300,000	5,566	120,000	22
Radiometric						
Gamma ray	2.5	25	300,000	10	120,000	12,000
Australia/New Zealand						
Land						
Seismic (*P*-wave)						
Dynamite	21.4	1,279	3,065,600	60	143,252	2,397
Vibratory	106.3	11,099	23,877,223	104	224,621	2,151
Gravity	1.0	[500]	40,000	[500]	40,000	[80]
Marine						
Seismic (*P*-wave)						
Compressed air	35.0	39,800	21,734,650	1,137	620,990	546
Gravity	3.0	13,694	43,000	4,565	14,333	3
Airborne						
Gravity	1.5	1,100	72,000	733	48,000	65
Magnetic	.5	3,600	45,000	7,200	90,000	13
Drill hole						
Sonic/velocity logging	5.0	(350,000)	210,000	(70,000)	42,000	(1)
Other	.5	(10,000)	38,000	(20,000)	76,000	(4)

(Continued from p. 35)

are combined with low cost, high production "flatland" surveys and can skew the averages. In the Eastern Hemisphere, acquisition costs per mile for land seismic decreased 5.8 percent, while marine costs increased 16.4 percent. The total number of miles of seismic data recorded worldwide was down 24.2 percent for land and down 5.6 percent for marine work as compared to 1986 levels. Distribution of expenditures, line-miles, and crew months on seismic activity is shown on Tables 3 and 5 which do not include activity reported for transition zone areas.

Vibroseis was again the most popular land seismic energy source used this year with dynamite the second most used source. These two energy sources accounted for 97 percent of all seismic land work in 1987. In marine work, the compressed air energy source was the most popular source, with air guns shooting 99 percent of the total line-miles recorded (see Table 6).

One can refer to Table 7 for a more comprehensive breakdown of statistical data on petroleum surveys, which are sorted by geographic area. Table 8 shows petroleum seismic activity by states in the U.S. Against a 1987 decline rate of 21 percent for overall onshore geophysical expenditures, California, Florida, Idaho, Michigan, Missouri, North Dakota, and Utah had increases in geophysical expenditures. Michigan passed Texas (in total expenditures) for the first time in the history of this report to lead all other states in seismic activity in 1987.

Michigan and Texas accounted for 41.4 percent of all U.S. onshore expenditures on seismic exploration. Louisiana and California accounted for 11 and 10 percent, respectively. Wyoming, Colorado, and Oklahoma were the only other states with expenditures greater than $10 million in 1987 and accounted for 6, 5, and 5 percent of the expenditures, respectively. The states with the largest decreases in 1987 were Alaska, Arkansas, Kansas, Mississippi, New Mexico, and Texas. No activity was reported from the following states that had activity in 1986: Connecticut, Delaware, Indiana, Maryland, New York, Pennsylvania, Virginia, and West Virginia.

Most of the marine seismic activity in the U.S. waters was recorded along the Gulf Coast. All the transition zone data reported were from the Gulf Coast area as well. Tables 9 and 10 show petroleum seismic activity was down in 1987 compared to 1986 but Canada had increased activity in land and transition zone areas.

A 56-year history of seismic exploration in the U.S. is shown in Figure 5.

Gravity and magnetic surveys

Table 11 shows worldwide expenditures for gravity and magnetic surveys. The 1987 data show a slight 3.3 percent increase in expenditures in these methods as compared to 1986. Expenditures on gravity and magnetic surveys for petroleum exploration were up 25 percent. Australia/New Zealand was the largest user of these methods for mineral exploration in 1987.

Airborne surveys

Statistical data on airborne surveys are shown in Tables 12, 13A, and 13B. Expenditures for worldwide airborne surveys increased by 10 percent from 1986. The major increase was in petroleum exploration which was up 92 percent in 1987 compared to 1986.

(Text continued on p. 47)

Table 8. U.S.A. petroleum seismic activity by area.

Survey type, state	Acquisition costs – US$	Line-miles	Crew-months		Crew-months total*
			Company*	Contract	
Land					
Undesignated	660,000	500	.0	4.0	4.0
Alaska	1,632,124	170	.0	5.0	5.0
Alabama	3,383,419	577	.0	17.5	17.5
Arkansas	20,399	6	.0	.5	.5
Arizona	160,000	50	.0	1.0	1.0
California	24,020,270	5,710	23.6	89.2	112.8
	[628,000]	[21]	[1.0]		[1.0]
Colorado	11,552,046	4,419	22.5	86.8	109.3
Florida	4,439,000	172	8.0	.0	8.0
Georgia	28,000	35	.0	.2	.2
Idaho	400,000	80	.0	2.0	2.0
Indiana	65,628	28	.7	.0	.7
Kansas	2,052,897	794	.0	19.3	19.3
Louisiana	22,228,383	3,706	1.0	90.1	91.1
Michigan	49,864,057	10,324	88.0	207.9	295.9
Missouri	361,972	102	.0	4.0	4.0
Mississippi	3,234,714	476	9.6	4.4	14.0
Montana	6,536,399	1,153	7.7	20.2	27.9
North Carolina	125,000	160	.0	1.7	1.7
North Dakota	7,076,888	1,543	3.1	33.9	37.0
Nebraska	1,175,750	378	.0	9.5	9.5
New Mexico	5,679,948	1,697	6.5	39.3	45.8
Nevada	896,000	186	0	6.1	6.1
Ohio	944,697	472	.0	11.8	11.8
Oklahoma	11,494,222	3,060	4.5	75.0	79.5
Oregon	1,924,000	640	.0	10.0	10.0
South Carolina	519,500	195	4.0	.5	4.5
South Dakota	28,000	6	.0	.1	.1
Tennessee	262,000	64	.0	2.0	2.0
Texas	44,759,330	12,268	33.1	282.6	315.7
	[650,000]	[41]	[3.0]		[3.0]
Utah	5,231,905	646	.0	20.5	20.5
Washington	4,505,000	333	15.5	.0	15.5
Wyoming	12,791,190	2,499	1.2	62.8	64.0
	[626,000]	[23]		[1.7]	[1.7]
Total land	228,052,738	52,449	229.0	1,108.1	1,337.1
	[1,904,000]	[85]	[4.0]	[1.7]	[5.7]
Transition zone					
Gulf Coast	1,000,000	300	.0	10.0	10.0
Marine					
Gulf Coast	83,477,975	232,047	54.2	137.2	191.4
	[4,140,000]	[11,600]		[16.0]	[16.0]
West Coast	16,176,000	31,680	.0	22.3	22.3
Total marine	99,653,975	263,727	54.2	159.5	213.7
	[4,140,000]	[11,600]		[16.0]	[16.0]
Total U.S.A.	328,706,713	316,476	283.2	1,277.6	1,560.8
	[6,044,000]	[11,685]	[4.0]	[17.7]	[21.7]

*Total includes government and university activity, if any.

All data enclosed in [brackets] pertain to 3-D surveys reported in square miles.

Table 9. Canada petroleum seismic activity by area.

Survey type, province	Acquisition costs - US$	Line-miles	Crew-months		Crew-months total*
			Company*	Contract	
Land					
Undesignated	17,633,000	3,836	.0	67.5	67.5
Alberta	82,636,430	23,540	45.6	203.0	248.6
	[7,274,784]	[381]		[22.6]	[22.6]
British Columbia	10,325,453	3,165	1.0	20.0	21.0
Manitoba	930,000	188	3.0	.0	3.0
Saskatchewan	6,896,455	1,702	20.1	19.1	39.2
Total land	118,421,338	32,431	69.7	309.7	379.4
	[7,274,784]	[381]		[22.6]	[22.6]
Transition zone					
Alberta	1,300,000	95	.0	1.5	1.5
Marine					
Undesignated	2,100,000	1,400	.0	3.0	3.0
Total Canada	121,821,338	33,926	69.7	314.2	383.9
	[7,274,784]	[381]		[22.6]	[22.6]

*Total includes government and university activity, if any.

All data enclosed in [brackets] pertain to 3-D surveys reported in square miles.

Table 10. Petroleum seismic activity in Mexico.

Survey type	Acquisition costs - US$	Line-miles	Crew-months		Total months
			Company	Contract	
Land					
Various	9,189,237	6,578	.0	181.0	181.0
Marine					
Various	1,900,000	7,100	.0	4.0	4.0
Total Mexico	11,089,237	13,678	.0	185.0	185.0

Table 11. Total worldwide expenditures on gravity and magnetic surveys in US$ (thousands).

Area	Petroleum		Minerals	Environmental	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
	Exploration	Development								
International									1,529	1,529
U.S.A.	7,258	32	1,528	83	27	7	84	300	72	9,393
Canada	936		1,434						55	2,426
Mexico	565									565
South America	1,031									1,031
Europe	1,132		726		208				12	2,079
Africa	3,381		731						100	4,213
Middle East	18						75			93
Far East	1,628		240			90			34	1,992
Australia/ New Zealand	200		1,755	26		20			792	2,793
Total	16,152	32	6,416	109	235	117	160	300	2,595	26,119

Table 12. Total worldwide expenditures on airborne surveys in US$ (thousands).

Area	Petroleum		Minerals	Environmental	Oceanography	Research	Total
	Exploration	Development					
U.S.A.	6,304	32	1,901	85	300	5	8,627
Canada	889		6,042	7			6,938
Mexico							
South America	979		106				1,086
Europe	946		2,759			38	3,743
Africa	2,187		1,261			15	3,463
Middle East	18						18
Far East	1,963						1,963
Australia/ New Zealand	117		1,634			744	2,495
Total	13,404	32	13,705	92	300	802	28,335

Table 13A. Western Hemisphere airborne activity in US$ (thousands).

	USA		Canada		South America	
	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Gravity	1,050	105			1,500	106
Magnetic	668,413	8,028	55,985	1,189	27,200	873
Electromagnetic						
VLF			2,000	50		
Combined EM/Mag.						
Time domain	581	36	30,055	989		
Frequency domain	2,000	300	35,000	2,700		
VLF			49,616	1,502	1,242	106
Radiometric						
Gamma ray	2,895	158	28,610	507		
Total	674,939	8,627	201,266	6,938	29,942	1,086

Table 13B. Eastern Hemisphere airborne activity in US$ (thousands).

Survey method	Europe		Africa		Middle East		Far East		Australia/New Zealand	
	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Gravity									1,100	72
Magnetic	30,700	958	115,073	2,828	2,000	18	34,916	1,363	254,700	2,418
Electromagnetic										
Frequency domain							13,916	300		
Combined EM/Mag.										
Time domain			12,114	635						
Frequency domain	43,164	2,759								
Radiometric										
Gamma ray	500	26					25	300		
Remote sensing										
Multispectral scanning									50	5
Total	74,364	3,743	127,187	3,463	2,000	18	48,857	1,963	255,850	2,495

Table 14A. Western Hemisphere land mining activity in US$ (thousands).

Survey method	USA Line-miles [stations]	USA Cost	Canada Line-miles [stations]	Canada Cost	Mexico Line-miles [stations]	Mexico Cost
Seismic (*P*-wave)						
Weight drop	[18]	3				
Vibratory			314	550		
Seismic (refraction)						
Dynamite	5	60				
Weight drop	6	11				
Gravity			400	80		
Gravity	[800]	18	[650]	287		
Magnetic			2,546	767		
Magnetic	[99]	20				
Resistivity	[20]	1				
Electromagnetic						
Time domain	25	25	438	315		
Frequency domain	390	95	130	33		
VLF			84	5		
Combined EM/Mag.						
Time domain			105	52		
Frequency domain			630	178		
VLF	145	86	245	133		
Induced polarization						
Time domain	94	140	812	829	5	5
Time domain	[80]	17				
Frequency domain	112	157	30	40		
Complex resistivity	1	25				
Magnetotelluric						
Natural field	85	7				
Controlled source	31	33	140	300		
Controlled source	[81]	20				
Remote sensing						
Multispectral scanning	2,000	20				
Other			[2]	9		
Total	2,894	742	5,874	3,581	5	5
	[1,098]		[652]			

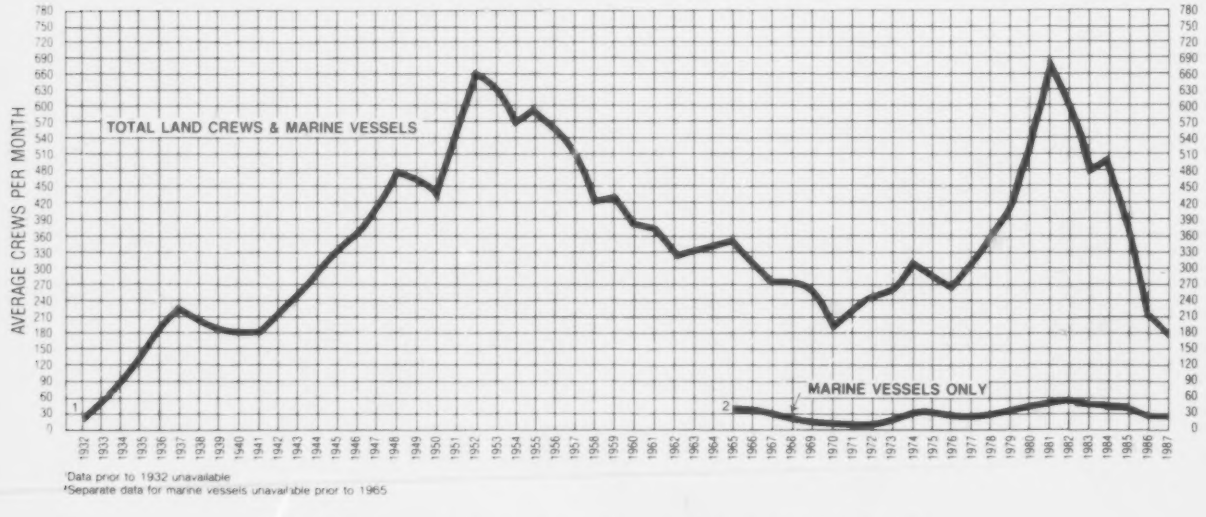
AVERAGE CREWS PER MONTH
TOTAL LAND CREWS & MARINE VESSELS
MARINE VESSELS ONLY
1
2
1Data prior to 1932 unavailable
2Separate data for marine vessels unavailable prior to 1965

FIG 5. History of seismic exploration activity in the U.S., 1932-1987.
(The total crews working in a given year is not synonymous with the crew-months worked that year.)

Table 14B. Eastern Hemisphere land mining activity in US$ (thousands).

Survey method	Europe		Africa		Far East		Australia / New Zealand	
	Line-miles (footage) [stations]	Cost	Line-miles (footage) [stations]	Cost	Line-miles (footage) [stations]	Cost	Line-miles (footage) [stations]	Cost
Seismic (*P*-wave)								
Weight drop							200	470
Vibratory			984	2,852				
Seismic (*S*-wave)								
Dynamite	[153]	1,900						
Seismic (refraction)								
Dynamite			1	2	5	4		
Gravity	444	282	900	10				
Gravity	[9,020]	389	[12,900]	50	[15,617]	156	[400]	26
Magnetic	207	54	1,217	45			55	100
Magnetic					[84,329]	84		
Resistivity	250	60	227	38	3	4		
Resistivity					(6,825)	7		
Resistivity			[15]	5	[15,289]	152		
Self-potential					2	1		
Self-potential					[79,840]	400		
Electromagnetic								
Time domain	40	34	74	38				
Time domain			[10]	5				
Frequency domain	38	16	126	6				
Frequency domain					[17,659]	100		
VLF	177	65			6	1		
Combined EM / Mag.								
Time domain			97	1		26	80	
Frequency domain	1,892	600			4	4		
VLF					6	5		
Induced polarization								
Time domain	327	152	90	41	467	466		
Radiometric								
Gamma ray			125	6				
Remote sensing								
Thermal infrared							[300]	34
Total	3,375	3,554	3,841	3,101	498	1,381	281	710
					(6,825)			
	[9,173]		[12,925]		[212,734]		[700]	

(Continued from p. 42)

Land mining

Tables 14A and 14B report expenditures and methods utilized for land mining in the Western and Eastern Hemispheres.

Engineering, geothermal, groundwater, oceanography and research

Table 15 reports engineering and groundwater activity. Table 16 contains worldwide geothermal work. Average unit costs for all survey objectives, types, and methods can be found in Table 17. Expenditures for groundwater and engineering activity are down 20 percent (Table 15). Geothermal activity is down from the previous year with a decrease in expenditures of 2 percent. Oceanography expenditures decreased by 51 percent and research decreased by 25 percent when compared to 1986 numbers.

Summary

Expenditures continued to show a major decline in 1987 for use of geophysics in the petroleum area worldwide. Areas affected the most were the U.S., Australia / New Zealand, Mexico, Europe, and Africa. These regions all showed an approximate 25-55 percent decrease in expenditures between 1986 and 1987. Activity in mining and engineering increased slightly while all other objectives declined.

It is felt by the committee that this is probably the best reported year in several years. This is true for two reasons: first, there are fewer companies to contact, and second, a more diligent effort was made this year to contact all companies.

(Text continued on p. 56)

Table 15. Worldwide groundwater and engineering activity.

Survey method	Area			Time *		Cost
	Line-miles	Stations	Footage	Crew-months	Man-months	US$ (thousands)
Seismic (*P*-wave)						
Dynamite	13			.4	.5	120.0
Compressed air	5,800			12.0		2,100.0
Electrical	2,230			16.4	37.8	4,658.0
Gas exploder	178			5.0		570.0
Implosive	481			3.8		1,092.5
Weight drop	22			2.2		159.0
Other	2			3.7		50.0
Seismic (*S*-wave)						
Weight drop	3				4.5	38.5
Seismic (refraction)						
Dynamite	150	57		8.4	2.7	380.3
Weight drop	17			6.5	2.2	130.9
Solid chemical	11			3.2	8.0	226.7
Passive monitoring	120			12.0		250.0
Other	13				1.3	13.0
Gravity	20	6,863	15,000	11.5	2.6	394.4
Magnetic	20			.5		2.0
Resistivity	3,765	711	89,284	96.5	23.8	1,631.8
Self-potential	30	6	31,025	1.0	3.1	53.5
Sonic/velocity logging		12	14,200		4.6	58.2
Electromagnetic						
Time domain	1	48		.3	1.5	13.4
Frequency domain	8	24			1.9	18.0
VLF	20				.7	30.5
Induced polarization						
Time domain			7,000		.4	5.6
Magnetotelluric						
Natural field	6			.7		2.3
Controlled source		172		1.0		47.5
Radiometric						
Gamma ray	4	18	47,046	3.6	13.0	114.0
Neutron activation		2				1.7
Remote sensing						
Microwave radiometry	30			1.0		50.0
Temperature gradient			25,091	1.0	.2	52.0
Other	1,276	3	2,260	5.7	8.7	437.9
Total	14,223	7,916	230,906	196.7	117.8	12,701.9

*Includes government and university activity.

Table 16. Worldwide geothermal activity.

Survey method	Area		Time *		Cost
	Line-miles	Stations	Crew-months	Man-months	US$ (thousands)
Seismic (*P*-wave)					
Passive monitoring		20		31.0	65.0
Seismic (*S*-wave)					
Compressed air	6		1.0		100.0
Gravity		1,080	6.6		100.0
Magnetic		2,423	2.7		17.9
Resistivity	7	483	8.5	5.0	105.3
Self-potential		140	.5		7.5
Magnetotelluric					
Natural field	16	85	5.2		678.8
Controlled source		60	.4		20.0
Temperature gradient		10	2.0		30.0
Total	29	4,301	26.9	36.0	1,124.5

*Includes government and university activity.

Table 17. Worldwide average unit costs by survey objective, type, and method.

Survey objective, type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew-month or man-month*	Average cost/mile or (foot) or [station]
Petroleum exploration						
Land						
Seismic (*P*-wave)						
Dynamite	1,575.9	82,908	319,463,906	53	202,711	3,853
Compressed air	43.2	2,742	10,990,317	63	254,405	4,007
Implosive	1.0	38	774,000	38	774,000	20,368
Weight drop	44.9	3,114	7,956,782	69	176,935	2,555
Vibratory	1,600.8	101,638	331,445,597	63	207,044	3,261
Seismic (*S*-wave)						
Dynamite	1.0	50	500,000	50	500,000	10,000
Compressed air	10.0	120	1,260,000	12	126,000	10,500
Vibratory	4.3	48	563,600	11	131,070	11,742
Other	9.0	345	1,800,000	38	200,000	5,217
Seismic (refraction)						
Dynamite	6.0	220	975,000	37	162,500	4,432
Dynamite	78.7*	942	6,600,000	12*	83,863*	7,006
Weight drop	1.3*	33	230,000	25*	176,923*	6,970
Vibratory	2.5	255	200,000	102	80,000	784
Vibratory	1.5*	61	240,000	41*	160,000*	3,934
Gravity	87.6	9,317	1,087,720	106	12,417	117
Gravity	37.5	[22,749]	1,387,016	[607]	36,987	[61]
Gravity	8.2*	240	48,000	29*	5,854*	200
Magnetic	13.5	530	56,000	39	4,148	106
Resistivity	37.0	1,850	444,000	50	12,000	240
Resistivity	1.0*	[4]	15,000	[4]*	15,000*	[3,750]
Electromagnetic						
Time domain	1.0	105	120,000	105	120,000	1,143
Magnetotelluric						
Natural field	15.0	[203]	436,287	[14]	29,086	[2,149]
Controlled source	.5	6	15,000	12	30,000	2,500
Controlled source	1.0	[100]	33,000	[100]	33,000	[330]
VSPs	58.3	[193]	1,581,216	[3]	27,122	[8,193]
3-D seismic						
Line-miles	144.4	9,836	26,547,637	68	183,848	2,699
Square miles	27.2	433	8,550,784	16	313,790	19,711
Other	3.0	[100]	413,000	[33]	137,667	[4,130]
Other	1.2*	[35]	60,000	[28]*	48,000*	[1,714]
Transition zone						
Seismic (*P*-wave)						
Dynamite	1.0	94	219,000	94	219,000	2,330
Compressed air	27.5	1,725	5,433,000	63	197,564	3,150
Marine						
Seismic (*P*-wave)						
Compressed air	556.6	572,404	271,021,190	1,028	486,923	474
Electrical	7.0	401	800,000	57	114,286	1,995
Gravity	29.7	74,521	590,000	2,505	19,832	8
Magnetic	2.0	7,177	179,000	3,589	89,500	25
VSPs	.2	[2]	83,800	[10]	419,000	[41,900]
3-D seismic						
Line-miles	53.0	75,781	22,083,664	1,429	416,359	291
Square miles	16.0	11,600	4,140,000	725	258,750	357
Airborne						
Gravity	4.7	3,650	283,000	768	59,579	78
Magnetic	179.4	747,869	12,521,845	4,168	69,791	17

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Survey objective, type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Petroleum exploration, Airborne, continued						
Electromagnetic						
Frequency domain	2.5	13,916	300,000	5,566	120,000	22
Radiometric						
Gamma ray	2.5	25	300,000	10	120,000	12,000
Drill hole						
Sonic/velocity logging	5.0	(350,000)	210,000	(70,000)	42,000	(1)
Other	3.0	(69,300)	262,000	(23,100)	87,333	(4)
Petroleum development						
Land						
Seismic (*P*-wave)						
Dynamite	40.0	1,178	8,833,000	29	220,825	7,498
Compressed air	1.0	40	200,000	40	200,000	5,000
Vibratory	26.2	1,174	8,274,209	45	315,810	7,048
3-D seismic						
Line-miles	1.0	87	305,000	87	305,000	3,506
Square miles	1.0	21	628,000	21	628,000	29,905
Other	4.0	[12]	72,000	[3]	18,000	[6,000]
Marine						
Seismic (*P*-wave)						
Compressed air	7.0	3,108	2,308,355	444	329,765	743
Electrical	50.0*	10	1,600,000	1*	32,000*	160,000
VSPs	3.2	[10]	205,000	[3]	64,063	[20,500]
VSPs	1.0*	[3]	54,000	[3]*	54,000*	[18,000]
3-D seismic						
Line-miles	7.0	10,771	4,165,559	1,539	595,080	387
Airborne						
Magnetic	.2	1,800	32,000	9,000	160,000	18
Drill hole						
Other	24.0*	[15]	240,000	[1]*	10,000*	[16,000]
Minerals						
Land						
Seismic (*P*-wave)						
Weight drop	9.0	200	470,000	22	52,222	2,350
Weight drop	3.0	[18]	3,000	[6]	1,000	[167]
Seismic (*P*-wave)						
Vibratory	14.0	1,298	3,402,000	93	243,000	2,621
Seismic (*S*-wave)						
Dynamite	1.8*	[153]	1,900,000	[85]*	1,055,556*	[12,418]
Seismic (refraction)						
Dynamite	3.1	12	66,220	4	21,361	5,473
Weight drop	2.3	6	11,600	3	4,979	1,933
Gravity	1.0	50	30,000	50	30,000	600
Gravity	48.6	[39,287]	920,940	[808]	18,949	[23]
Gravity	89.0*	1,694	342,000	19*	3,843*	202
Gravity	1.0*	[100]	6,000	[100]*	6,000*	[60]
Magnetic	44.7	2,738	751,650	61	16,797	274
Magnetic	10.9	[84,428]	104,000	[7,746]	9,541	[1]
Magnetic	32.0*	1,287	216,300	40*	6,759*	168
Resistivity	9.5	378	94,500	40	9,947	249
Resistivity	10.0	[15,289]	152,900	[1,529]	15,290	[10]
Resistivity	4.4*	102	8,800	23*	1,978*	86

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Survey objective, type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Minerals, Land, continued						
Resistivity	3.0*	[35]	6,000	[12]*	2,000*	[171]
Self-potential	1.0	2	1,200	2	1,200	545
Self-potential	16.0	[79,840]	400,000	[4,990]	25,000	[5]
Electromagnetic						
Time domain	19.2	553	404,800	29	21,083	732
Time domain	4.0*	24	8,000	6*	2,000*	333
Time domain	1.0*	[10]	5,000	[10]*	5,000*	[500]
Frequency domain	6.2	504	113,100	81	18,242	224
Frequency domain	5.0	[17,659]	100,000	[3,532]	20,000	[6]
Frequency domain	10.9*	185	39,150	17*	3,575*	212
VLF	3.5	87	5,580	25	1,594	64
VLF	17.0*	181	66,500	11*	3,896*	367
Combined EM/Mag.						
Time domain	7.7	131	132,000	17	17,143	1,008
Time domain	.3*	97	950	323*	3,167*	10
Frequency domain	10.7	334	122,670	31	11,411	367
Frequency domain	149.0*	2,192	660,700	15*	4,434*	301
VLF	16.2	325	176,350	20	10,852	542
VLF	2.5*	71	49,000	28*	19,600*	690
Induced polarization						
Time domain	51.6	1,393	1,446,950	27	28,015	1,039
Time domain	.6	[80]	17,753	[133]	29,588	[222]
Time domain	86.0*	402	187,000	5*	2,174*	465
Frequency domain	10.5	142	197,600	14	18,819	1,387
Complex resistivity	.5	1	25,000	2	50,000	20,833
Magnetotelluric						
Natural field	2.5	85	7,500	34	3,000	88
Controlled source	8.0	171	333,000	21	41,625	1,947
Controlled source	.5	[81]	20,793	[162]	41,586	[257]
Radiometric						
Gamma ray	3.0	32	4,000	11	1,333	125
Gamma ray	2.5*	93	2,500	37*	1,000*	27
Remote sensing						
Thermal infrared	.5*	[300]	34,000	[600]*	68,000*	[113]
Multispectral scanning	1.0	2,000	20,000	2,000	20,000	10
Other	2.0*	[2]	9,000	[1]*	4,500*	[4,500]
Marine						
Other	1.0	50	62,000	50	62,000	1,240
Airborne						
Magnetic	47.7	319,380	4,045,800	6,689	84,729	13
Electromagnetic						
VLF	1.0	2,000	50,000	2,000	50,000	25
Combined EM/Mag.						
Time domain	5.3	42,750	1,660,800	7,991	310,430	39
Frequency domain	12.5	80,164	5,759,000	6,413	460,720	72
VLF	5.4	27,453	586,461	5,084	108,604	21
VLF	37.4*	23,405	1,022,968	626*	27,352*	44
Radiometric						
Gamma ray	5.5	30,160	575,000	5,484	104,545	19
Remote sensing						
Multispectral scanning	.1	50	5,000	500	50,000	100
Drill hole						
Resistivity	1.0	(6,825)	7,000	(6,825)	7,000	(1)

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Survey objective, type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Minerals, Drill hole, continued						
Electromagnetic						
Time domain	.1	(4,500)	5,000	(45,000)	50,000	(1)
Induced polarization						
Time domain	.8	(55,000)	26,500	(64,706)	31,176	(1)
Time domain	.1*	(900)	1,500	(9,000)*	15,000*	(2)
Radiometric						
Gamma ray	4.0*	(28,100)	18,000	(7,025)*	4,500*	(1)
Environmental						
Land						
Seismic (*P*-wave)						
Weight drop	2.5	13	33,000	5	13,043	2,538
Seismic (*S*-wave)						
Dynamite	.2	2	10,000	8	40,000	5,000
Seismic (refraction)						
Weight drop	1.2	9	21,000	7	17,073	2,333
Weight drop	.5	[5]	10,000	[10]	20,000	[2,000]
Weight drop	.8*	1	6,000	1*	7,500*	6,000
Passive monitoring	3.0*	[8]	12,000	[3]*	4,000*	[1,500]
Other	.3*	4	4,000	13*	13,333*	1,000
Gravity	.2*	5	1,000	25*	5,000*	200
Gravity	.4*	[41]	8,000	[103]*	20,000*	[195]
Magnetic	2.7	162	26,000	59	9,455	160
Magnetic	2.0	[600]	30,000	[300]	15,000	[50]
Magnetic	2.3*	24	23,000	10*	9,787*	958
Magnetic	.2*	[380]	19,000	[1,900]*	95,000*	[50]
Resistivity	.5	10	1,500	20	3,000	150
Resistivity	.7	[7]	19,000	[9]	25,333	[2,714]
Resistivity	.6*	1	12,000	3*	20,000*	8,000
Resistivity	.9*	[64]	13,000	[71]*	14,444*	[203]
Electromagnetic						
Frequency domain	.5	15	20,000	30	40,000	1,333
Frequency domain	5.3*	72	112,500	14*	21,226*	1,552
VLF	.2	[394]	5,252	[1,970]	26,260	[13]
Combined EM/Mag.						
Frequency domain	2.0*	40	50,000	20*	25,000*	1,250
Magnetotelluric						
Natural field	1.0	12	3,000	12	3,000	250
Airborne						
Magnetic	.2	100	2,000	400	8,000	20
Radiometric						
Gamma ray	1.1	1,345	90,000	1,223	81,818	67
Drill hole						
Resistivity	.5*	(8,500)	28,250	(14,655)*	48,707*	(3)
Resistivity	.5*	(1,000)	4,000	(2,000)*	8,000*	(4)
Self-potential	.2*	(6,000)	22,000	(30,000)*	110,000*	(4)
Sonic/velocity logging	.3*	(2,500)	6,250	(6,579)*	16,447*	(3)
Induced polarization						
Time domain	.3*	(2,500)	6,250	(6,579)*	16,447*	(3)
Radiometric						
Gamma ray	.5*	(8,500)	28,250	(14,655)*	48,707*	(3)

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Survey objective, type and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Engineering						
Land						
Seismic (*P*-wave)						
Dynamite	.5*	12	95,000	24*	190,000*	7,917
Electrical	.5	40	45,000	80	90,000	1,125
Electrical	.8*	60	33,000	75*	41,250*	550
Weight drop	2.2	22	159,000	10	70,667	7,227
Other	.7	1	10,000	1	13,333	20,000
Seismic (*S*-wave)						
Weight drop	4.0*	2	32,500	1*	8,125*	12,500
Seismic (refraction)						
Dynamite	7.2	58	186,390	8	25,709	3,192
Dynamite	.2	[57]	5,000	[285]	25,000	[88]
Dynamite	2.7*	12	39,000	4*	14,182*	3,250
Weight drop	6.5	12	107,400	2	16,523	8,950
Weight drop	.6*	3	10,500	5*	16,154*	3,387
Solid chemical	3.2	7	121,700	2	37,446	16,903
Solid chemical	8.0*	4	105,000	1*	13,125*	26,250
Passive monitoring	12.0	120	250,000	10	20,833	2,083
Other	.8*	8	8,000	10*	10,000*	1,000
Gravity	5.5	[4,444]	208,868	[808]	37,976	[47]
Gravity	.7*	10	2,000	14*	2,857*	200
Gravity	1.0*	[400]	25,000	[400]*	25,000*	[63]
Resistivity	3.0	97	20,720	33	6,907	212
Resistivity	9.5	[427]	411,180	[45]	43,282	[963]
Resistivity	6.1*	61	61,000	10*	10,000*	1,000
Resistivity	1.6*	[25]	31,000	[16]*	19,375*	[1,240]
Self-potential	2.0*	30	20,000	15*	10,000*	667
Electromagnetic						
Frequency domain	.4*	8	8,000	18*	17,778*	1,000
Frequency domain	1.5*	[24]	10,000	[16]*	6,667*	[417]
VLF	.7*	20	30,500	27*	40,667*	1,525
Other	5.0	10	1,325	2	265	133
Other	.2*	1	660	5*	3,300*	660
Other	3.5*	[3]	60,000	[1]*	17,143*	[20,000]
Marine						
Seismic (*P*-wave)						
Compressed air	12.0	5,800	2,100,000	483	175,000	362
Electrical	15.9	2,111	3,470,000	133	218,239	1,644
Electrical	37.0*	19	1,110,000	1*	30,000*	58,421
Gas exploder	5.0	178	570,000	36	114,000	3,202
Implosive	3.8	481	1,092,500	127	287,500	2,271
Other	.7	1,265	237,000	1,687	316,000	187
Drill hole						
Resistivity	2.4*	(9,912)	30,600	(4,130)*	12,750*	(3)
Resistivity	.2*	(800)	2,000	(4000)*	10,000*	(3)
Self-potential	.4*	(7,000)	5,600	(17,500)*	14,000*	(1)
Sonic/velocity logging	4.4*	(12,200)	45,600	(2,773)*	10,364*	(4)
Induced polarization						
Time domain	.4*	(7,000)	5,600	(17,500)*	14,000*	(1)
Radiometric						
Gamma ray	.5*	(9,400)	6,600	(18,800)*	13,200*	(1)
Temperature gradient	.2*	(4,500)	2,000	(22,500)*	10,000*	(1)
Other	5.0*	(2,260)	139,000	(452)*	27,800*	(62)

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Survey objective, type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Geothermal						
Land						
Seismic (*P*-wave)						
Passive monitoring	31.0*	[20]	65,000	[1]*	2,097*	[3,250]
Seismic (*S*-wave)						
Compressed air	1.0	6	100,000	6	100,000	16,667
Gravity	6.6	[1,080]	100,000	[164]	15,152	[93]
Magnetic	2.7	[2,423]	17,900	[897]	6,630	[7]
Resistivity	1.0	7	63,000	7	63,000	9,000
Resistivity	7.5	[373]	37,300	[50]	4,973	[100]
Resistivity	5.0*	[110]	5,000	[22]*	1,000*	[45]
Self-potential	.5	[140]	7,500	[280]	15,000	[54]
Magnetotelluric						
Natural field	1.2	16	3,800	13	3,040	238
Natural field	4.0	[85]	675,000	[21]	168,750	[7,941]
Controlled source	.4	[60]	20,000	[150]	50,000	[333]
Drill hole						
Temperature gradient	2.0	[10]	30,000	[5]	15,000	[3,000]
Groundwater						
Land						
Seismic (*P*-wave)						
Dynamite	.4	1	25,000	4	62,500	16,667
Other	3.0	2	40,000	1	13,333	20,000
Seismic (*S*-wave)						
Weight drop	.5*	1	6,000	1*	12,000*	8,571
Seismic (refraction)						
Dynamite	1.0	80	150,000	80	150,000	1,875
Weight drop	1.6*	2	13,000	1*	8,125*	5,909
Other	.5*	5	5,000	10*	10,000*	1,000
Gravity	3.0	[1,916]	105,952	[639]	35,317	[55]
Gravity	.4*	10	2,000	25*	5,000*	200
Gravity	.5*	[103]	20,600	[206]*	41,200*	[200]
Magnetic	.5	20	2,000	40	4,000	100
Resistivity	77.5	3,606	890,750	47	11,494	247
Resistivity	5.5	[175]	24,150	[32]	4,391	[138]
Resistivity	1.0*	1	5,000	1*	5,000*	12,500
Resistivity	8.3*	[84]	49,000	[10]*	5,868*	[583]
Self-potential	.1*	[6]	5,000	[120]*	100,000*	[833]
Sonic/velocity logging	.1*	[12]	10,000	[120]*	100,000*	[833]
Electromagnetic						
Time domain	.3	1	1,440	3	4,800	1,440
Time domain	1.5*	[48]	12,000	[32]*	8,000*	[250]
Magnetotelluric						
Natural field	.7	6	2,300	8	3,067	383
Controlled source	1.0	[172]	47,500	[172]	47,500	[276]
Radiometric						
Gamma ray	12.0*	4	20,000	1*	1,667*	5,000
Gamma ray	.1*	[18]	16,200	[120]*	108,000*	[900]
Neutron activation	.1*	[2]	1,700	[40]*	34,000*	[850]
Remote sensing						
Microwave radiometry	1.0	30	50,000	30	50,000	1,667
Drill hole						
Gravity	3.0	(15,000)	30,000	(5,000)	10,000	(2)

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Survey objective, type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Groundwater, Drill hole, continued						
Resistivity	1.0	(20,591)	50,000	(20,591)	50,000	(2)
Resistivity	4.2*	(57,981)	56,400	(13,740)*	13,365*	(1)
Self-potential	.6*	(17,200)	15,900	(26,462)*	24,462*	(1)
Self-potential	1.0	(6,825)	7,000	(6,825)	7,000	(1)
Sonic/velocity logging	.1*	(2,000)	2,600	(20,000)*	26,000*	(1)
Radiometric						
Gamma ray	3.6	(30,046)	61,960	(8,346)	17,211	(2)
Gamma ray	.4*	(7,600)	9,300	(19,000)*	23,250*	(1)
Temperature gradient	1.0	(20,591)	50,000	(20,591)	50,000	(2)
Oceanography						
Marine						
Seismic (*P*-wave)						
Electrical	.5	500	100,000	1,000	200,000	200
Electrical	1.7*	6,245	508,000	3,674*	298,824*	81
Implosive	.4	350	100,000	875	250,000	286
Other	2.5	9,000	750,000	3,600	300,000	83
Airborne						
Magnetic	.5*	15,000	300,000	30,000*	600,000*	20
Research						
Land						
Seismic (*P*-wave)						
Dynamite	3.3	64	323,500	19	98,030	5,055
Weight drop	4.0	30	152,500	8	38,125	5,083
Weight drop	.3*	1	3,000	2*	10,000*	6,000
Vibratory	5.5	340	1,484,800	62	269,964	4,367
Seismic (*S*-wave)						
Compressed air	1.0	5	100,000	5	100,000	20,000
Vibratory	12.0	240	20,000	20	1,667	83
Seismic (refraction)						
Dynamite	1.0	30	10,000	30	10,000	333
Weight drop	.2*	1	3,000	1*	15,000*	15,000
Passive monitoring	4.0*	300	20,000	75*	5,000*	67
Gravity	2.0	615	6,500	308	3,250	11
Gravity	15.4	[11,115]	134,000	[722]	8,701	[12]
Gravity	.2*	1	1,000	8*	5,000*	667
Gravity	27.0*	[8,850]	92,000	[328]*	3,407*	[10]
Magnetic	.2*	1	1,000	8*	5,000*	667
Resistivity	1.5	9	32,000	6	21,333	3,556
Resistivity	.5	[5]	20,000	[10]	40,000	[4,000]
Resistivity	8.0*	[48]	25,000	[6]*	3,125*	[521]
Self-potential	.5	25	17,000	50	34,000	680
Electromagnetic						
Time domain	1.0	60	100,000	60	100,000	1,667
Frequency domain	5.0	82	85,000	16	17,000	1,037
Frequency domain	.4	[20]	40,000	[50]	100,000	[2,000]
Combined EM/Mag.						
Frequency domain	3.0*	[5]	15,000	[2]*	5,000*	[3,000]
Induced polarization						
Time domain	.5	2	5,000	4	10,000	2,500
Magnetotelluric						
Natural field	7.7	490	21,700	64	2,818	44
Natural field	2.5	[108]	285,000	[43]	114,000	[2,639]
Natural field	1.5*	[20]	60,000	[13]*	40,000*	[3,000]

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Survey objective, type, and method	Total crew-months or man-months*	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or man-month*	Average cost/ crew month or man-month*	Average cost/mile or (foot) or [station]
Research, Land, continued						
Controlled source	1.0	[13]	20,000	[13]	20,000	[1,538]
Radiometric						
Gamma ray	.5	1	40,000	2	80,000	40,000
Remote sensing						
Microwave radiometry	1.0	30	50,000	30	50,000	1,667
VSPs	2.0	1	50,000	1	25,000	45,455
Marine						
Seismic (*P*-wave)						
Compressed air	6.7	21,072	2,394,331	3,140	356,830	114
Gravity	1.9	13,990	282,576	7,363	148,724	20
Magnetic	4.0	28,754	1,246,964	7,189	311,741	43
3-D seismic						
Line-miles	1.0	2,000	1,046,116	2,000	1,046,116	523
Other	4.2	6,500	1,220,000	1,529	287,059	188
Airborne						
Magnetic	10.1	104,038	761,000	10,301	75,347	7
Magnetic	1.0*	800	15,000	800*	15,000*	19
Radiometric						
Gamma ray	1.0	500	26,000	500	26,000	52
Drill hole						
Magnetic	1.5	(9,000)	55,000	(6,000)	36,667	(6)
Resistivity	.2*	(9,979)	4,000	(36,959)*	14,815*	(1)
Self-potential	.1*	(9,679)	3,000	(74,454)*	23,077*	(1)
Induced polarization						
Time domain	1.5	(9,000)	55,000	(6,000)	36,667	(6)
Radiometric						
Gamma ray	1.5	(9,000)	55,000	(6,000)	36,667	(6)
Gamma ray	1.2*	(33,036)	10,000	(26,429)*	8,000*	(1)
Temperature gradient	.5	(10,000)	2,000	(20,000)	4,000	(1)

(Continued from p. 47)

Acknowledgments

This report was made possible through the contributions of statistical data by companies, contractors, governmental agencies, and universities. For many of these organizations, compilation of these data was a long and tedious task. The Geophysical Activity Committee expresses sincere appreciation to all those individuals who were instrumental in preparing and submitting their activity questionnaires. The committee welcomes comments and suggestions on ways to improve this report.

Karen Goodfellow, Assistant Chairman, was responsible for much of the work in obtaining and maintaining the accuracy of these data for the Geophysical Activity Report. A special note of thanks goes to Karen Goodfellow and Michelle Wolfe, my assistant, and to Stan Jones, Jerry Henry, Sue Schulze, Jane Salas, and the rest of the SEG staff who worked on this project. I would also like to thank H. T. Konkler for the long hours he worked with the computer. Every member of the Geophysical Activity Committee should be congratulated for help and advice in determining the direction of the work, updating address lists, and analyzing computer printouts for correctness.

References

Geophysical Activity in 1986 LEADING EDGE, August 1987, 25-49.

Published by
Society of Exploration Geophysicists
P.O. Box 702740
Tulsa, Oklahoma 74170-2740
U.S.A.

Printed in USA